REMARKS

Before examination of the application and calculation of the filing fee, please enter the following amendment. The amendment removes the word "pre-fragmented" from the title, abstract, specification and claims. Applicant submits that with these changes, the Examiner's objection to the disclosure has been overcome. Newly added claims 21-30 are patentable over the cited art.

The Commissioner is authorized to charge any additional fees or credit any overpayment to Deposit Account No. 20-1504 (SHL.0227US)

Respectfully submitted,

Date: June 24, 2003

Fred G. Pruner, Jr., Reg. No. 40,779
TROP, PRUNER & HU, P.C.
8554 KATY FREEWAY, SUITE 100
(713)468-8880 [Phone]
(713) 468-8883 [Fax]

CLEAN VERSION

SHAPED CHARGE

FIELD OF THE INVENTION

[0001] The subject matter of the present invention relates to a shaped charge for use in perforating operations. More specifically, the subject matter of the present invention relates to controlling the debris generated by the shaped charges during perforating.

BACKGROUND OF THE INVENTION

[0002] In drilling operations, the drilled hole is often lined with a casing to prevent the earth from filling the hole. In order for the surrounding fluid to enter the drilled hole, the well casing must be perforated. Such operation is typically performed by a perforating gun loaded with one or more shaped charges.

[0003] Conventional shaped charges produce significant debris upon detonation. If small enough, the generated debris can exit the gun carrier and enter the well fluid and become entrained in the well fluid. The exit of the debris can occur both during detonation and during the retrieval process of the carrier to the surface. As the debris is carried by the well fluid, it can complicate down stream processing of the well fluids by clogging filters and jamming pumps, for example.

[0004] There exists, therefore, a need for controlling the size of debris generated during perforating operations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1 is a cross-sectional view of a typical shaped charge, loading tube, and hollow carrier.

[0006] Figure 2 is a perspective view of a typical shaped charge and loading tube.

[0007] Figure 3 is a perspective view of a loading tube being inserted into a hollow carrier.

[0008] Figure 4 illustrates an embodiment of the shaped charge.

[0010] Figure 5 provides a top view of an embodiment of the charge case having 6 slots.

[0011] Figure 6 provides a top view of an embodiment of the charge case having 2 slots.

[0012] Figure 7 provides a top view of an embodiment of the charge case having 4 slots.

[0013] Figure 8 illustrates an embodiment of the charge casing having V-notch slots.

[0014] Figure 9 illustrates an embodiment of the charge casing having U-notch slots.

[0015] Figure 10 illustrates an embodiment of the charge case having internal slots.

[0016] Figure 11 illustrates an embodiment of the charge case having circumferential slots.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0017] Figure 1 provides an illustration of a typical shaped charge, indicated generally as **1**, used for perforating a well casing. Typical shaped charges for use in perforating guns are discussed in U.S. Pat. No. 4,724,767 to Aseltine issued Feb. 16, 1988; U.S. Pat. No. 5,413,048 to Werner et al. issued May 9, 1995; U.S. Pat. No. 4,669,384 to Chawla et al. issued Jun. 2, 1987; and again in U.S. Pat. No. 5,597,974 to Voreck, Jr. et al. issued Jan. 28, 1997. Each of the above mentioned disclosures are incorporated by reference into this specification.

[0018] A typical shaped charge **1** includes a case **10**, a main body of explosive material **12**, which in the past has been, for example, RDX, HMX, PYX, or HNS packed against the inner wall of the case **10**, a primer **13** disposed adjacent the main body of explosive **12** that is adapted to detonate the main body of explosive **12** when the primer **13** is detonated, and a liner **14** lining the primer **13** and the main body of explosive material **12**. The liner **14** acts to maintain the shape of the explosive to assure proper propagation of the detonation. A detonating cord **20** contacts the case **10** of the shaped charge **1** at a point nearest the apex of the liner **14** of the charge. When a detonation wave propagates within the detonating cord **20**, the detonation wave will detonate the primer **13**. When the primer **13** is detonated, the detonation of the primer **13** will further detonate the main body of explosive **12** of the charge **1**. In response to the detonation of the main body of explosive **12**, the liner **14** will form a jet that will propagate along a longitudinal axis of the shaped charge **1**. The jet will perforate a formation penetrated by the wellbore.

[0019] One or more shaped charges **1** are housed within a loading tube **22** for transport. The loading tube **22** can house the shaped charges **1** at desired orientations, or in a linear fashion. A jacket **24** is used to both secure the shaped charges **1** to the loading tube **22** and to maintain the orientation of the shaped charges **1**. Once the loading tube **22** is ready for delivery downhole, a hollow carrier **30** is used to carry the loading tube **22** and housed shaped charges **1**.

[0020] In one conventional use shown in Figs. 2 and 3, the shaped charges **1** and jackets **24** are inserted into the loading tube **22** until the jackets **24** shoulder against the loading tube shoulders **23**. Once all of the shaped charges **1** are secured, the loading tube **22** is inserted into the interior of the hollow carrier **30**. The hollow carrier **30** then transports the shaped charges **1** downhole to the desired depth of perforation.

[0021] It should be noted that the above description of the convention shaped charges **1** is intended for illustration only and not intended to limit the scope of the present invention. The present invention is equally applicable for use in alternate shaped charges and carriers. For example, the present invention can be used with equal applicability with jacket-less shaped charges.

[0022] Figure 4 illustrates one embodiment of the shaped charge, indicated generally as **40**, of the present invention. Slots, or grooves, **42** are cut into the charge case **44** to weaken the case **44** according to a certain pattern or design. Upon detonation of the shaped charge **40**, the case material is subject to explosion forces and will undergo stretching in its hoop direction. Because the slots **42** are cut in the axial direction orthogonal to the hoop stretching, the slots **42** define weakening lines along the stretching direction. As a result, the charge case **44** will fracture along these lines of weakness. In this manner, the shaped charge **40** can be used to control the size and shape of the debris generated by the charge case **44** during perforating operations. The slots **42** in the shaped charge **40** can also be used to channel the explosion energy in certain directions. Such channeling of explosive energy improves the survivability of the gun carrier **30**.

[0023] As shown in Figures 5-7, the shaped charge **40** can be designed with any number of slots **42**. As examples, Figure 5 displays a charge case **44** having 6 slots **42**, Figure 6 displays a charge case **44** having 2 slots **42**, and Figure 7 displays a charge case **44** having 4 slots **42**. It should be understood that any number of slots **42** can be cut into the charge case **44** depending upon the application. Because the distance between the slots **42** controls the size of

the generated debris, for applications in which it is desired to make the debris larger than the exit hole in the hollow carrier **30** (shown in Figure 3), the shaped charge **40** may have fewer slots **42**. Conversely, when it is desired to make the debris very small, such as when the shaped charge **40** is used for spiral or strip guns, the charge case **44** may have many slots **42**.

[0024] In addition to variances in the number of slots **42**, the slots **42** cut into the charge case **44** can be of multiple shapes and sizes. Figures 8 and 9 illustrate two example slot **42** designs. In Figure 8, the slot **42** cut into the wall of the case **44** is a V-notch groove, while in Figure 9, the slot **42** cut into the wall of the case **44** is a U-notch groove. The shape and depth of the slot **42** controls the timing of the breakup of the charge case **44**.

[0025] Another embodiment of the shaped charge **40** is illustrated in Figure 10. In this embodiment, the slots **42** are cut on the internal surface of the charge case **40**.

[0026] Yet another embodiment of the shaped charge **40** is illustrated in Figure 11. In this embodiment, the slots **42** are oriented circumferentially around the charge case **40**. The circumferential slots **42** can be internal or external.

[0027] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such are intended to be included within the scope of the following non-limiting claims.

MARKED-UP VERSION

~~PRE-FRAGMENTED~~ SHAPED CHARGE

FIELD OF THE INVENTION

[0001] The subject matter of the present invention relates to a ~~pre-fragmented~~ shaped charge for use in perforating operations. More specifically, the subject matter of the present invention relates to controlling the debris generated by the shaped charges during perforating.

BACKGROUND OF THE INVENTION

[0002] In drilling operations, the drilled hole is often lined with a casing to prevent the earth from filling the hole. In order for the surrounding fluid to enter the drilled hole, the well casing must be perforated. Such operation is typically performed by a perforating gun loaded with one or more shaped charges.

[0003] Conventional shaped charges produce significant debris upon detonation. If small enough, the generated debris can exit the gun carrier and enter the well fluid and become entrained in the well fluid. The exit of the debris can occur both during detonation and during the retrieval process of the carrier to the surface. As the debris is carried by the well fluid, it can complicate down stream processing of the well fluids by clogging filters and jamming pumps, for example.

[0004] There exists, therefore, a need for controlling the size of debris generated during perforating operations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1 is a cross-sectional view of a typical shaped charge, loading tube, and hollow carrier.

[0006] Figure 2 is a perspective view of a typical shaped charge and loading tube.

[0007] Figure 3 is a perspective view of a loading tube being inserted into a hollow carrier.

[0008] Figure 4 illustrates an embodiment of the ~~pre-fragmented~~ shaped charge.

[0009] Figure 5 provides a top view of an embodiment of the ~~pre-fragmented~~ charge case having 6 slots.

[0010] Figure 6 provides a top view of an embodiment of the ~~pre-fragmented~~ charge case having 2 slots.

[0011] Figure 7 provides a top view of an embodiment of the ~~pre-fragmented~~ charge case having 4 slots.

[0012] Figure 8 illustrates an embodiment of the ~~pre-fragmented~~ charge casing having V-notch slots.

[0013] Figure 9 illustrates an embodiment of the ~~pre-fragmented~~ charge casing having U-notch slots.

[0014] Figure 10 illustrates an embodiment of the ~~pre-fragmented~~ charge case having internal slots.

[0015] Figure 11 illustrates an embodiment of the ~~pre-fragmented~~ charge case having circumferential slots.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0016] Figure 1 provides an illustration of a typical shaped charge, indicated generally as **1**, used for perforating a well casing. Typical shaped charges for use in perforating guns are discussed in U.S. Pat. No. 4,724,767 to Aseltine issued Feb. 16, 1988; U.S. Pat. No. 5,413,048 to Werner et al. issued May 9, 1995; U.S. Pat. No. 4,669,384 to Chawla et al. issued Jun. 2, 1987; and again in U.S. Pat. No. 5,597,974 to Voreck, Jr. et al. issued Jan. 28, 1997. Each of the above mentioned disclosures are incorporated by reference into this specification.

[0017] A typical shaped charge **1** includes a case **10**, a main body of explosive material **12**, which in the past has been, for example, RDX, HMX, PYX, or HNS packed against the inner wall of the case **10**, a primer **13** disposed adjacent the main body of explosive **12** that is adapted to detonate the main body of explosive **12** when the primer **13** is detonated, and a liner **14** lining the primer **13** and the main body of explosive material **12**. The liner **14** acts to maintain the shape of the explosive to assure proper propagation of the detonation. A detonating cord **20** contacts the case **10** of the shaped charge **1** at a point nearest the apex of the liner **14** of the charge. When a detonation wave propagates within the detonating cord **20**, the detonation wave will detonate the primer **13**. When the primer **13** is detonated, the detonation of the primer **13** will further detonate the main body of explosive **12** of the charge **1**. In response to the detonation of the main body of explosive **12**, the liner **14** will form a jet that will propagate along a

longitudinal axis of the shaped charge **1**. The jet will perforate a formation penetrated by the wellbore.

[0018] One or more shaped charges **1** are housed within a loading tube **22** for transport. The loading tube **22** can house the shaped charges **1** at desired orientations, or in a linear fashion. A jacket **24** is used to both secure the shaped charges **1** to the loading tube **22** and to maintain the orientation of the shaped charges **1**. Once the loading tube **22** is ready for delivery downhole, a hollow carrier **30** is used to carry the loading tube **22** and housed shaped charges **1**.

[0019] In one conventional use shown in Figs. 2 and 3, the shaped charges **1** and jackets **24** are inserted into the loading tube **22** until the jackets **24** shoulder against the loading tube shoulders **23**. Once all of the shaped charges **1** are secured, the loading tube **22** is inserted into the interior of the hollow carrier **30**. The hollow carrier **30** then transports the shaped charges **1** downhole to the desired depth of perforation.

[0020] It should be noted that the above description of the convention shaped charges **1** is intended for illustration only and not intended to limit the scope of the present invention. The present invention is equally applicable for use in alternate shaped charges and carriers. For example, the present invention can be used with equal applicability with jacket-less shaped charges.

[0021] Figure 4 illustrates one embodiment of the ~~pre-fragmented~~ shaped charge, indicated generally as **40**, of the present invention. Slots, or grooves, **42** are cut into the charge case **44** to weaken the case **44** according to a certain pattern or design. Upon detonation of the ~~pre-fragmented~~ shaped charge **40**, the case material is subject to explosion forces and will undergo stretching in its hoop direction. Because the slots **42** are cut in the axial direction orthogonal to the hoop stretching, the slots **42** define weakening lines along the stretching direction. As a result, the charge case **44** will fracture along these lines of weakness. In this manner, the ~~pre-fragmented~~ shaped charge **40** can be used to control the size and shape of the debris generated by the charge case **44** during perforating operations. The slots **42** in the ~~pre-fragmented~~ shaped charge **40** can also be used to channel the explosion energy in certain directions. Such channeling of explosive energy improves the survivability of the gun carrier **30**.

[0022] As shown in Figures 5-7, the ~~pre-fragmented~~ shaped charge **40** can be designed with any number of slots **42**. As examples, Figure 5 displays a charge case **44** having 6

slots **42**, Figure 6 displays a charge case **44** having 2 slots **42**, and Figure 7 displays a charge case **44** having 4 slots **42**. It should be understood that any number of slots **42** can be cut into the charge case **44** depending upon the application. Because the distance between the slots **42** controls the size of the generated debris, for applications in which it is desired to make the debris larger than the exit hole in the hollow carrier **30** (shown in Figure 3), the ~~pre-fragmented~~ shaped charge **40** may have fewer slots **42**. Conversely, when it is desired to make the debris very small, such as when the shaped charge **40** is used for spiral or strip guns, the charge case **44** may have many slots **42**.

[0023] In addition to variances in the number of slots **42**, the slots **42** cut into the charge case **44** can be of multiple shapes and sizes. Figures 8 and 9 illustrate two example slot **42** designs. In Figure 8, the slot **42** cut into the wall of the case **44** is a V-notch groove, while in Figure 9, the slot **42** cut into the wall of the case **44** is a U-notch groove. The shape and depth of the slot **42** controls the timing of the breakup of the charge case **44**.

[0024] Another embodiment of the ~~pre-fragmented~~ shaped charge **40** is illustrated in Figure 10. In this embodiment, the slots **42** are cut on the internal surface of the charge case **40**.

[0025] Yet another embodiment of the ~~pre-fragmented~~ shaped charge **40** is illustrated in Figure 11. In this embodiment, the slots **42** are oriented circumferentially around the charge case **40**. The circumferential slots **42** can be internal or external.

[0026] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such are intended to be included within the scope of the following non-limiting claims.